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# Characteristics of pulse magnetron discharge with power supply from a capacitor energy storage

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*The peculiarities of pulse sputtering magnetron discharge in conditions of low-voltage power supply from capacitor energy storage are considered. Discharge current-voltage characteristics is shown to depend on pulse duration. The pulse packet regime ensures stable arc-free maintenance of the discharge at long time operation.*

## 1. Introduction

Magnetron sputtering systems (MSS) are widely used in thin film technology, however, the practice constantly brings forth new problems and development of new more efficient MSS does not interrupted. The abilities of MSS in many respects are defined by their operation mode and power supply features. As an example of this, one can mention the intensively developed pulse sputtering [1]. The new approach allows to reduce working temperature at high power level, to increase an instantaneous plasma density and to stimulate chemical reactions on coated surfaces, to prevent glow-to-arc transitions on magnetron targets in reactive gases. Different circuits can be used for pulse discharge generation. A large charged capacitor periodically connected to a magnetron may be employed for this goal, too. The capacitor serves as an energy storage and a current transformer for a power supply source that is the discharge current magnitude can be much higher than the maximum permissible current of the power source. However the capacitor appears as a constant voltage which equals to the burning voltage of magnetron discharge and commonly is less than the firing voltage. The paper deals with the peculiarities of pulse magnetron operation with such energy source.

## 2. Experimental set-up

The experiments were performed using sputter deposition machine Z550M with planar "balanced magnetic field" magnetrons. A schematic drawing of the pulse magnetron circuit is shown in Fig. 1, where E – primary power source (controlled thyristor rectifier SSV-3.5) operating in constant mean power mode, C – capacitor energy storage, VT – switch IGBT transistor, VD – isolation diode, $R_l$ – ballast resistor for the auxiliary discharge (starting-up glow) with low current of 10-30 mA, PA – peak ampermeter. A capacitor/transistor circuit is known to have near-zero output impedance and this allows to have very high discharge current which is defined in such case only by magnetron current-voltage characteristics (CVC) [2]. A small resistor $R_0$ was employed for limiting the maximum current in the magnetron circuit.

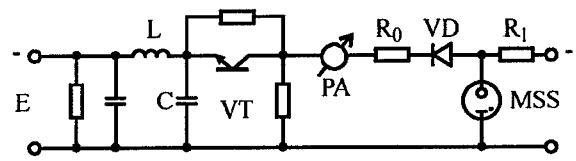


Fig.1. Schematic drawing of the MSS circuit

## 3. Results and discussion

Fig.2 shows diagrams of discharge voltage and current where $\tau$ – pulse duration, $\tau_f$ – formative time for pulse discharge or fall time for magnetron voltage.

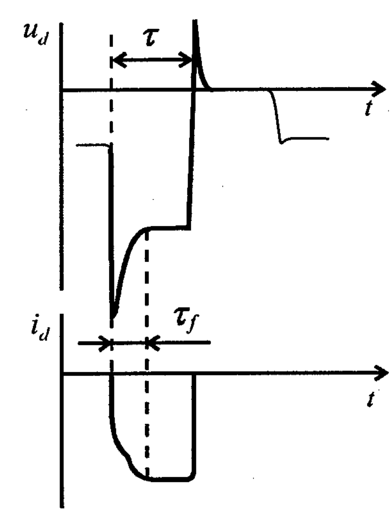


Fig.2. Discharge voltage ($u_d$) and current ($i_d$) diagrams

Fig.2 clearly demonstrates the delay in building-up of pulse discharge current after pause. The value of $\tau_f$ is about 50 µs at Ar pressures of 0.2-3 Pa and peak currents of up to 30 A that is much bigger than $\tau_f \sim 5$ µs in case of the modulator on the base of electronic tubes

[3]. In our case, the value of E (400-600 V) is close to the maintaining or burning voltage of the magnetron discharge; in [3], E was about 2 kV and this voltage was applied to the magnetron during the formative time. Fig. 3 shows CVC of the pulse magnetron discharge at the end of current pulses for different $\tau$. One can see the smaller $\tau$ the higher the discharge resistance is and only after 100 μs CVC becomes independent on $\tau$. Thus, at small $\tau$ the pulse discharge operates in high-voltage mode and the square-wave current becomes triangular.

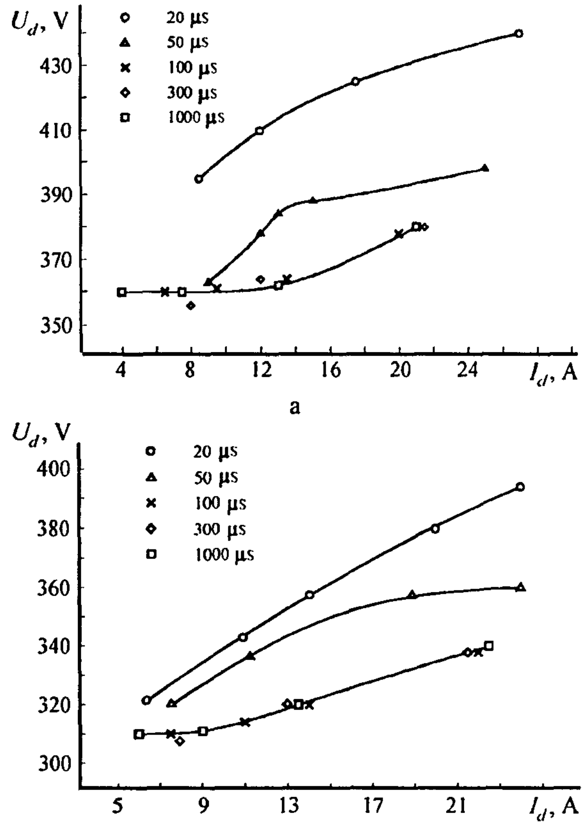


Fig.3. Current voltage characteristics of the magnetron discharge at Ar pressures of 0.19 Pa (a) and 2 Pa (b). Target material is Ti.

The thin line in Fig.2 is a voltage diagram of the auxiliary discharge which creates primary ionization, this glow discharge stabilizes arising and maintenance of the powerful pulse discharge [3]. When auxiliary discharge was put out the delay in firing pulse discharge may be very large up to some milliseconds. The near-zero voltage period after current pulse is a result of excess afterglow plasma conductivity and this period may serve as a measure of plasma decay time.

Adding reactive gases ($N_2$, $CH_4$, etc) to the discharge chamber is known to cause sparking and arcing on the magnetron target [1,2] but when we used short pulses ($\tau < 50$ μs at $I_d$ of up to 30 A) these phenomena vanished as we decreased the time for charging dielectric films on the target. Electron current from decaying afterglow plasma and, maybe, the positive voltage overshootings (Fig.2) promote discharging the films and prevent from accumulation of the critical positive charge. However we have the problem how to work with long pulses. Obviously, the best approach is splitting long pulses into short pulses with small current pauses between them that is use pulse packets instead of continuos long pulses. Such a pulse regime was proposed and successfully employed earlier [3,4]. Fig.4 shows oscillograms for discharge in the pulse packet mode and one can see the stable arc-free work of the magnetron with graphite target is possible even at $\tau$ in second'th range.

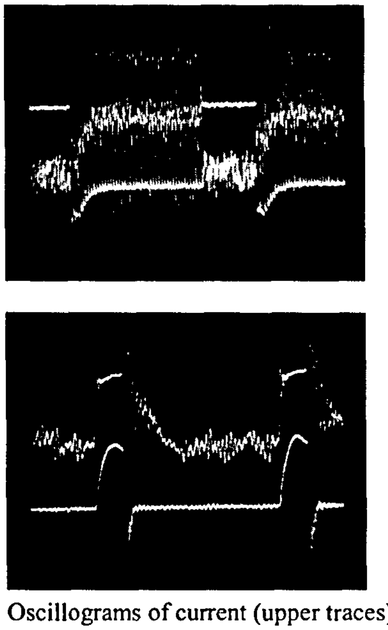

Fig.4. Oscillograms of current (upper traces) and voltages (lower traces) in the pulse packet regime. The upper oscillogram (2 s/div) shows whole packets, the lower oscillogram (20 μs/div) shows three pulses, separated by pauses of 20 μs, from the packet. Material of the target is graphite. Polarity of signals is negative.

## 4. References


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